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Defense Against Biological and Chemical Threats

Chemical and biological attacks on military personnel can cause major loss of life and have a profound impact on the ability of military organizations to complete their missions. SPO has taken a specific approach to these threats that will be discussed here. Also addressed are other ways battlefield casualties might be reduced.

The protection of our people on the battlefield, as well as the protection of high-value buildings, from both chemical and biological attack, is a priority. The military's current approach, the Mission Oriented Protective Posture (MOPP), envisions that a Soldier would be able to fight at the highest level of protection, or MOPP-4. The problem is the

Soldier would have to do so while wearing a chemical suit, boots, protective mask and gloves, often in a scorching desert. Clearly, the combat effectiveness of a soldier in MOPP-4 is greatly reduced.

SPO envisions boosting his combat effectiveness with the ability to perform standoff detection and decontamination. The program goal is to identify agents in a cloud in a one-minute timeframe, from a standoff distance of 10 kilometers, then deploy effective countermeasures to "kill the cloud."

The Threat Agent Cloud Tactical Intercept and Countermeasure program (TACTIC), would use a combination of rapid detection and effective countermeasures to defeat chemical and biological warfare agents before they can harm our warfighter. The TACTIC program is divided into two portions, detection and countermeasure. In the detection portion, material is delivered to the cloud that interacts with the threat particles and creates a signature that allows identification from a distance. In the countermeasure portion of the program, technologies that chemically attack the threat, coalesce the threat, and burn the threat, are being developed.

The TACTIC program has shown positive results in small scale tests. Assuming these results can be replicated at much larger scales, a second phase of TACTIC will be initiated. It is our intention to put out a broad agency announcement for the final phase of TACTIC near year's end. This phase will develop a complete end-to-end prototype system that can deliver the detection material, interrogate the cloud, and, if needed, use the countermeasure to destroy the cloud. The technologies for this phase are not limited to those already tested, we want to hear your good ideas for the end-to-end system.

The DARPA Immune Building program has progressed to the point of culmination, this year, with a demonstration of a completely functional immune building, Nord Hall at Ft. Leonard Wood in Missouri. This system will provide defenses against a wide range of chemical and biological warfare agents, whether they are released externally or within the building. The defenses include passive and active filtration systems and HVAC manipulation. This system will include automated command and control of the active systems and the HVAC manipulation. The lessons already learned from this program have been captured in simulation software called the Building Protection Toolkit. This toolkit can be used to:

- Design, from the ground up, an Immune Building system
- Model the effectiveness of the system against the spectrum of challenges
- Determine the cost of the Immune Building system in a new or retrofitted application.

One of the lessons learned during the Immune Building program is that all buildings have leaks—porous bricks, cracks in window seals, inadequately sealed HVAC systems. To close this vulnerability, SPO is interested in developing active building coatings that completely seal building facades, greatly improve the performance of shelter-in-place strategies, or reduce the burden on overpressurization systems. The coatings must be cost-effective and cannot change a building's appearance. The coatings must last for years, withstanding extremes of temperature as well as the effects of settling.

Self-assembling nano-structures show promise as a coating because of their ability to "self-heal" cracks. The coatings might even use embedded sensors to become "active coatings." These coatings can also be tailored to improve our ability to decontaminate buildings. SPO is looking for your best ideas on how to devise active protective coatings.

The US military can be the most effective at protecting high-value military targets from biological attack when an attack has been detected. This requires novel biological sensors with very high levels of performance. In approaching work on such novel technologies, think of the technology

needed for detecting a biological threat as a five-step process:

- First step is the collection of the sample
- Second step is to prepare the sample for detection
- Third step is to identify the threat agent
- Fourth step is to transduce the presence of the threat
- Fifth and final step is to analyze the transduction event and determine whether this a true positive or a false positive

As these new chemical and biological sensors are developed, it is also important to understand the three major response timescales where sensors are needed.

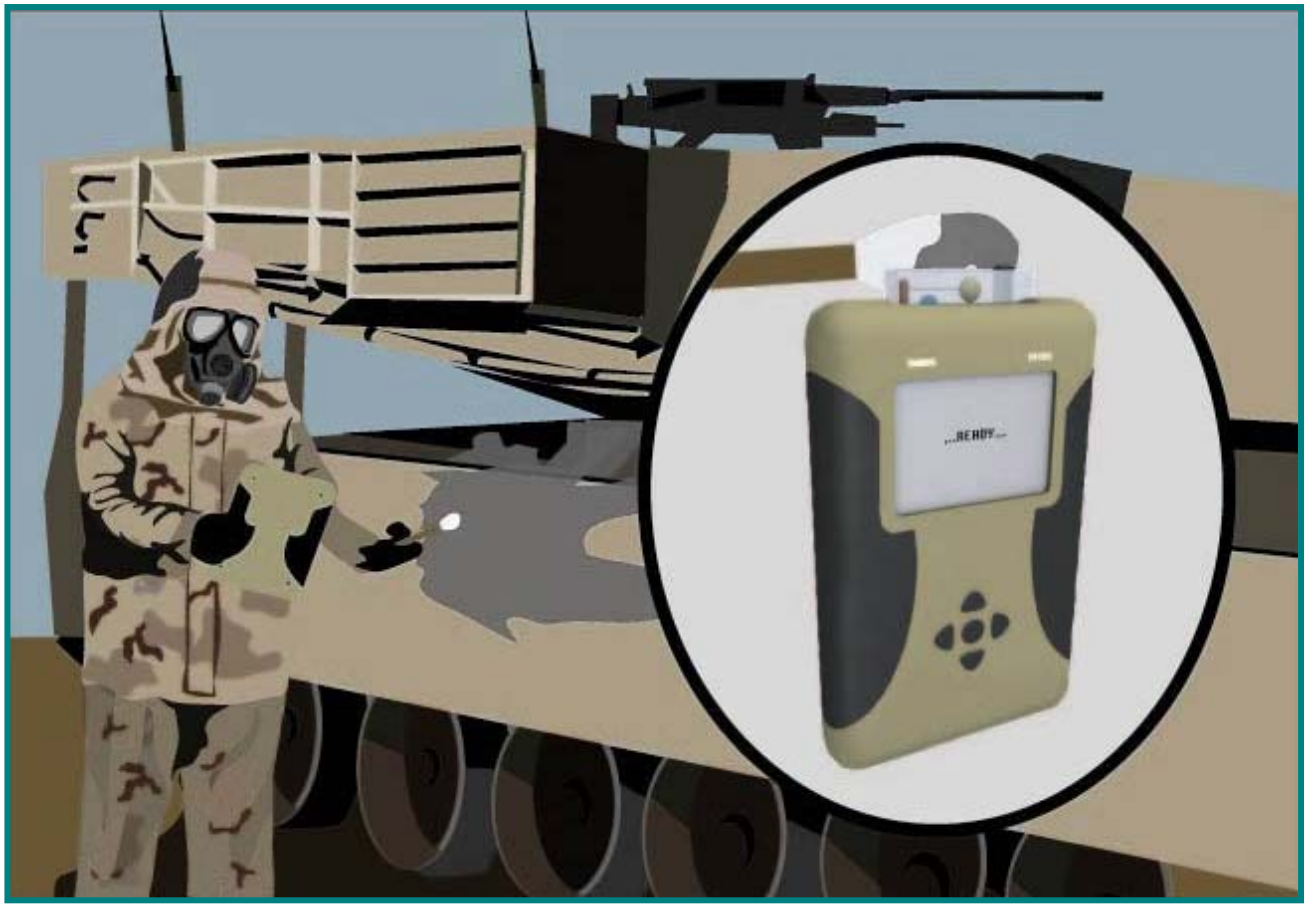
The first timescale covers the results of the detect-to-protect sensors, warning of a chemical or biological threat in seconds to minutes. These sensors enable active protection systems or evacuations.

The second timescale covers detect-to-treat, where a sensor detects an agent within hours to a day. These types of sensors enable treatments such as Cipro for anthrax.

The final timescale concerns detect-to-restore, quickly returning a building to full use. This timescale takes days to months and will require a new class of biological sensors.

An important tool for any Immune Building will be detect-to-protect sensors for biological, as well as chemical, attacks. SPO has two ongoing detect-to-protect biological sensor programs. The first, Spectral Sensing of Biological Aerosols (SSBAs), is developing new fast-trigger sensors that have very low false-alarm rates.

A spectral-based sensor Biological Agent Warning System has already been fielded by the US military. This fluorescence-based system has an



unacceptably high false-alarm rate and produces multiple alarms each day.

The false-alarm rate is a critical parameter. A high-regret response involves not just changes to HVAC, but also to the evacuation of people in the building. That is why the SSBA program aims to develop sensors with a false-alarm rate that is at least 10 times lower than our current sensor.

The aim is to detect a biological threat in 60 seconds or less. The approaches that have been evaluated in the SSBA program include:

- Mass spectrometry
- UV laser-induced fluorescence
- UV fluorescence lifetime
- Raman spectroscopy

Sensor developers are already entering Phase II of the program to design and build prototypes. These sensors are based on the idea that the best way to avoid a false alarm is to do a better job of identifying true threat particles. Of course, it is not enough to recognize an attack has occurred, we need to know what agent was used in the attack.

SPO's second detect-to-protect sensor program is the Handheld Isothermal Silver Standard Sensor (HISSS), based on isothermal techniques that replace today's laboratory silver standards, such as PCR, RT-PCR, and ELISA. The goal of the program is to enable battlefield detection of the full biological spectrum of bacteria, viruses, and toxins, using a handheld device. The applications of the HISSS device are not limited to the battlefield as the high speed of this sensor fits well into the Immune Building timeframes and will enable more high-regret responses.

On the battlefield, HISSS will give Soldiers a laboratory-quality way to detect biological agents within minutes. In head-to-head testing, against the silver-standard, HISSS assays showed significantly better false-alarm rates.

The bottom line is that both our HISSS and SSBA programs are developing ways to conduct the third, fourth, and fifth steps in the detection process: identification, transduction, and result analysis. But, there's a catch. These sensors can only detect threat particles that make it all the way through the 5-step detection process from sampling to result analysis.

This means that you cannot detect a threat until it gets all the way to the detection unit. What if your biological sensor is operating on the edge of a large biological attack? In the center of the attack, an air collector might pull in hundreds or even thousands of threat particles. But, on the edge of an attack, the air collector might pull in less than 10 particles. So, it is at the edge that the majority of these particles simply must make it to detection.

One way to do this is with air collectors that pull samples into milliliters of water. Unfortunately, biological detection reactions in water are conducted on the microliter scale, raising the likelihood that we might miss the particle of interest due to sampling error. For this reason, SPO is interested in detectors that can selectively collect biological particles and carry them into the detection reactions without dilution.

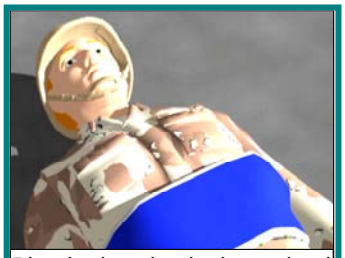
There is another place where these particles can be lost, in the sample preparation step. For many biological assays, the sample must be cleaned of contaminants; vegetative cells and spores must be lysed to make DNA available, and virus particles must be stripped of their coat proteins. Sonication is one potential way to isolate the particle of interest. But sonication sheds small metallic particles that interfere with the sensors. All of these steps involve manipulations or dilutions that can lose the particles of interest.

Novel sample preparation techniques are needed that can minimize the loss of the sample. This means we must control the adhesion of the sample to the surface, so we can select the molecule of interest and transport it into the detection reaction. SPO is interested in any ideas you may have to improve the likelihood that a single threat particle

will be captured, cleaned up, and moved through the reaction system.

The primary focus of this discussion has been on preventing and detecting attacks. But what if the attack has already occurred? Now the challenge is to detect-to-restore. How do we know we are clean? After an attack, biological particles can lodge in cracks and crevices and be difficult to detect.

Decontamination techniques such as chlorine dioxide are very effective at restoring buildings to use, but only if we can confirm their effectiveness. One of the main challenges is that existing detection technologies require sample collection and individual testing to prove that a threat is not in a crevice, a potentially dangerous bottleneck in determining the contamination level.


Bleeder location is determined


Ultrasonic cuff is applied


Coagulation is performed

A second challenge is that the decontamination technology may kill or denature the threat without enough structural change to prevent a false positive. Protein toxins offer a special challenge. Toxins can be denatured and made inactive by breaking apart the toxin's side chains. Unfortunately, the side chains can refold and the molecule can even regain its toxicity. We must know whether or not this redevelopment of toxicity has occurred. This means that SPO is not only interested in techniques that can detect chemical and biological threats *in situ*, but that we also want techniques that can tell us if the threat is still viable, whether it is live bacteria or an active toxin like Ricin. We would like to hear your ideas on how to detect viable agents.

On a completely different topic, American Soldiers, Sailors, Airmen, and Marines are dying on the battlefield today due to hemorrhage. SPO is developing systems for Combat Casualty Care to reduce this loss of life.

SPO's Deep Bleeder Acoustic Coagulation program is developing a fully automated device that will allow a battlefield Soldier to detect and stop bleeding with ultrasound. The concept is to create conformal arrays of imaging and high-power ultrasound transducers that surround the wound. This array of transducers will scan for the Doppler signature of the wound's flowing blood to detect the bleeder. Once one transducer detects this Doppler signature, it will signal the others to localize the puncture. The high-power transducers will then focus on the bleeder and coagulate the blood with heat.

Another battlefield problem is the rapid delivery of IV fluids to prevent shock. The US Army is preparing to train all of their medics as paramedics, and many Soldiers as combat lifesavers. This gives us a large pool of people who know how to start an IV with conventional equipment. Unfortunately, even the best-trained person must struggle to introduce an IV into a Soldier who is dehydrated or in shock. SPO is interested in developing techniques that will allow any Soldier to administer an IV, even to himself. Our approach, admittedly notional, is to insert a thin, hollow fiber into arm muscle that will "worm" its way toward the acoustic signature of the blood flow, reach the dead center of the vessel, and then dilate to allow fluids to be rapidly injected. We would be interested in any ideas you have to support this technology, or some alternative.

In all these areas, SPO is developing tools to protect the men and women who serve us so bravely and so well.